Georgia Tech Sponsored Research

6

Project	E-20-X52 B2379
Project director	Baker, N. Nelson
Research unit	CEE
Title	Intelligent Engineering Tutoring Systems
Project date	11/30/1999

E·20452
6

FINAL REPORT FOR AWARD # 9258205

Nelson Baker ; *GA Tech Res Corp - GIT*
NSF Young Investigator

Participant individuals:
Post-doc(s): Augusto Op den Bosch
Graduate student(s): Angela Birkes; Sean St. Clair; Michael Bertz; Marty Boyd; Susan Braun; Ananjan Roy Chowdhury; Sherry Farrow; Chandrasekar Gnanasambandam; Emily Haught; Omar El Kordy; Larry Llibre; Robert McConnell; Walter Patterson; Gordon Thompson; Chaisak Srisethanil

Participants' Detail

Partner organizations:
GE Foundation: Financial Support

The GE Foundation provided matching funds for this research and the activities provided a working relationship that used the products of this research for education about sustainability in the built environment. As a by-product of this interaction, I have lead a 40+ consortium of industry to donate a $4million dollar facility to Georgia Tech called the Sustainable Education Building (http://seb.ce.gatech.edu/). This web page provides details about the donors, their activities, and both still/video footage of the building's construction that has been used in many classes, both in the United States and internationally.

Atlanta Public Schools: Personnel Exchanges

Teachers from the Atlanta Public School System were participants in a summer eight week program. During this time, the teachers worked in the research lab, learning about multimedia, technology in education, and created a module with technology for their classroom.

Gwinnett County Public Schools: Personnel Exchanges

Teachers from the Gwinnett County Public School System were participants in a summer eight week program. During this time, the teachers worked in the research lab, learning about multimedia, technology in education, and created a module with technology for their classroom.

Cobb County School District: Personnel Exchanges

Teachers from the Cobb County Public School System were participants in a summer eight week program. During this time, the teachers worked in the research lab, learning about multimedia, technology in education, and created a module with technology for their classroom.

Other collaborators:

Through my activities in this project and its visibility at Georgia Tech, I was selected as the Georgia Tech Faculty Development Coordinator for SUCCEED. I have produced products, including a day long workshop on effective use of technology in the classroom for SUCCEED based upon the work in this research project. This has allowed me to interact with many people, both at Georgia Tech and at the other seven universities in SUCCEED.

Activities and findings:

Research Activities:

Major Research and Education Activities
+ Research Activities have included the study, creation, and assessment of:
- virtual reality in engineering education (interactive visualizer which has driven the development of a commercial tool - TerraVista)
- intelligent tutoring systems for engineering (ITS-Concrete, ITS-CPM)
- a student model for engineering undergraduates in structural courses (part of the ITS and in a problem generator) based on fuzzy logic
- database management systems for storing/query of engineering images/videos
- vertical and horizontal linkages for engineering content (Civil Engineering Learning Library - CELL)
- microworlds for specific engineering content (Trickshot!, Problem Generator for Reinforced Concrete Analysis/Design)
- comparison of multimedia content delivery vs. traditional lectures
- tools for assisting faculty in the creation of educational objectives in their courses allowing proper assessment and content focus (IOWA)
- engineering students retention of fundamental knowledge
- engineering students usage of visual information for understanding analysis/design scenarios
- capturing of a building construction from start to finish. This was for the Sustainable Education Building (http://seb.ce.gatech.edu) and the content of this web site is used internationally for instruction.

+ Educational Activities
- training of grades 6-12 teachers during summer sessions of 8 weeks
- training of graduate students in both the technology and in educational pedagogy (industry found these students to be highly desirable, to the point where many were hired before finishing their degrees and in many cases, the offers were so good that the student never finished their degree)
- training and assistance for faculty
- incorporation of the pedagogy and technology into the civil engineering undergraduate course on reinforced concrete analysis and design and slowly the ideas migrated into other courses
- results and assessments helped to shape the civil

engineering undergraduate structural sequence of courses in the semester conversion at Georgia Tech
- the School of Civil & Environmental Engineering web pages were an early product of this research and the educational course content has had input from this research
- the Civil Engineering Virtual Library was a result of this research (http://www.ce.gatech.edu/WWW-CE/home.html)
- the Civil Engineering distance learning activities within Georgia Tech are resulting from leverages of this work with demands for civil engineers in other portions of the State of Georgia

Activities and findings:

Research Findings:

Major findings

+ Faculty need assistance before the results of this research (and others like it) are to be implemented. They need help in learning how to best use technology (not just online course syllabi), how to incorporate technology into their teaching activities, how to engage students to use the technology to learn, and how to overcome their fears of not being in control of the classroom material presentation (pace and content) and fear of the course properly preparing a student for engineering.

+ Students also need assistance in that many embrace the technology, but often get 'caught up' in the graphics and not the content. Some students feel 'cheated' by using technology when they believe that they paid tuition for a faculty member, not a computer. Students also have a tendency to learn a computer interface as the end result of learning, rather than the content, so a minimization of interfaces is desirable.

+ Four components are necessary for dissemination of engineering knowledge: theory, examples, real world cases, and problems for the student to exercise their knowledge. These components apply to courses delivered with or without technology. These four components should have as much visual content as possible as most engineering students are visual learners.

+ Software tools and engineering teaching should be based upon student learning styles, faculty teaching styles, and include elements of active learning, reflection, scaffolding, and visualization. The software developed for this project utilized these concepts and also included Bloom's taxonomy for representing the various portions of the cognitive domain and Gagne's Instructional Design theory for content delivery.

+ Maintenance of developed software is an enormous challenge, both in physical computer uptime, but also in software revisions, knowledge content, and human resources to assist with the updates. Over the course of this grant there is now software that will no longer run due to software developed for what was state-of-the-art systems which no longer exist and are out-dated.

+ The visibility of this research project on faculty has been compelling. Faculty who did not believe in educational research now believe. Others have changed the way they instruct and in reality, how students learn. They have adaptedtechniques of collaboration, active learning, and technology in their classes where as previously they not only did not include these. The faculty by and large had never heard of these techniques. Using the scientific method of investigation was critical to sharing information and for gaining acceptance of the results with the engineering faculty.

+ Collaboration tools for engineering education must include methods to assist in sketching and/or drawing. Much of the content of engineering learning and practice revolves around visual representations, pictures, and models. Descriptions that are purely text based causes much confusion and quick abandonment of the tools.

+ The use of virtual reality stimulates many engineering students who tend to be visual learners. It also motivates the student and allows them to verify the results of engineering designs. However, it is not clear how students use these tools for learning, that is, how they capture the knowledge transmitted in visual form and how they remember such events. Our brief experience is that the transfer may be very contextually dependent to the images they saw and the engineering applications and knowledge need to be more broadly applied.

+ The need for visual understanding lead the School of Civil and Environmental Engineering at Georgia Tech to retain a freshman level course on engineering visualization in its semester based program (all courses were redone in the semester conversion process in 1997-1999). Mechanical and Aerospace engineering also require this course of their freshman.

+ The problem generator created for the senior level reinforced concrete analysis and design class captured both student and faculty interest in many arenas, including internationally. This tool allows the student to create their own homework problems, see examples of already solved problems, and will generate problems at the students request in one of nine learning objectives identified within the domain. The interface is web-based and is in both english and spanish.

By using the problem generator, students have a 24 hour a day tutor. A faculty interface that can see what students are doing and what difficulties the students are having is needed to make this package complete. The key to success is the three methods of obtaining information regarding the very specific learning objectives within the engineering domain. The materials availability over the web in two languages was also very popular, but most important was the graphic images that show the engineering problem and solution.

+ The organization of engineering material is critical. Work accomplished in this project shows the locations where knowledge is acquired, reused, retained, and lost. Vertically linking this knowledge thus becomes critical to allowing a student to move beyond fundamental knowledge in an introductory course and transfer that information into a deeper understanding of advanced topics. Advanced courses need to have explicit links back into fundamental material fostering and supporting a learners' recall. The Civil Engineering Learning Library (CELL) facilitated these actions in the structural engineering aspects of civil engineering.

+ As faculty attempted to use some of our results, it became clear that without good educational objectives, the task of transfer became very difficult as the expectations of each faculty were different. Thus, we created a website to assist faculty with the creation of educational objectives for their courses (see http://epitome.ce.gatech.edu/ and the link for IOWA).

+ Our work shows it is possible to create student models in engineering which can do a respectable job at predicting student difficulties in learning engineering topics. With these models and an understanding of the methods in which students learn, engineering content can be better learned by the student. These techniques work both with and without the use of technology. Many of these lessons have been captured in the Effective Teaching with Technology workbook that was co-sponsored by SUCCEED. The creation and use of intelligent tutors in engineering was also successful, but many other simpler techniques were more easily understood by faculty. In fact, the simpler techniques while not as elegant, were more accepted by faculty because they felt more 'in control' of the content dissemination.

+ The student models developed for this project were implemented via fuzzy logic to represent the non-crisp delineation of expertise and comprehension. The work shows that summer jobs and co-op experiences in engineering had the single most important impact on a student performing well in engineering classes and having the ability to comprehend engineering information - most likely due to their ability to contextualize the information better than students without these experiences.

+ Due to the importance of visual information in engineering education and practice, we undertook the study for a engineering database schema that supports images and video related to engineering activities. The schema was implemented and allows organization for storage and query of these visual media.

+ One of the most unexpected findings of this work has been the demand from industry for the people doing this research. The graduate students are highly recruited for both their technical knowledge in creating computer based media, but also for their unique understanding of and ability to describe engineering knowledge. Many of the graduate students were recruited while still in the beginning of their work and several did not complete their degrees due to job offers which were too compelling to refuse.

Research Training:

Opportunities for training and development

This project has contributed to the teaching and research skills of all the graduate students who have participated. These students have directly learned about both engineering and pedagogy. They have investigated the literature in cognitive science and have applied what they read to engineering. They have learned a research methodology along with their teaching skillsets. The project has also been able to take these lessons to both grade 6-12 teachers and to college faculty (see outreach activities below). Through these activities many engineering graduate students and faculty have heard about, and learned about engineering pedagogy and how technology can assist student learning.

Education and Outreach:

Outreach Activities

+ GIFT: allowed approximately ten 6-12 grade teachers to come and work in the research laboratory for eight weeks in a summer. These teachers learned about multimedia and computer technology, developed course material for their classrooms, and helped provide insight and pedagogy to our research activities.

+ SUCCEED: the research undertaken in this grant allowed the creation of a full day workshop entitled: Effective Teaching with Technology, that has been given to the SUCCEED annual conference, to Georgia Tech, to University of North Carolina Charlotte, and to all faculty development coordinators of the eight SUCCEED institutions for dissemination to their faculties.

Journal Publications:

N.C. Baker and P.S. Chinowsky, "Technology in the Civil Engineering Classroom: Introduction & Assessment", *American Society of Engineering Educators, Annual Conference*, vol. , (1996), p. 3515. Published

N.C. Baker and C. Srisethanil, "ITS-Engineering: Providing Adaptive Teaching in an Engineering Tutor", *Frontiers in Education, American Society of Engineering Educators*, vol. 1, (1995), p. 2a3.22. Published

N.C. Baker and C. Srisethanil, "Adaptive Instructor Model for An engineering ITS", *First congress on Computing in Civil Engineering*, vol. , (1994), p. 1059. Published

N.C. Baker and O. El Kordy, "Multimedia Implications to Structural Engineering", *Analysis and Computing, Procedings of the Eleventh Conference, American Society of Civil Engineers*, vol. , (1994), p. 37. Published

N.C. Baker, "Explanation Facilities for Intelligent Engineering Tutors", *Fifth International Conference on Computing in Civil Engineering, American Society of Civil Engineers*, vol. , (1993), p. 431. Published

M. Bertz and N.C. Baker, "CELL- A Vertically Integrated Learning Resource", *Third Congress on Computing in Civil Engineering, American Society of Civil Engineers*, vol. , (1996), p. 348. Published

M. Boyd and N.C. Baker, "A Distributed Engineering Problem Generator", *Third Congress on Computing in Civil Engineering, American Society of Civil Engineers*, vol. , (1996), p. 466. Published

C. Srisethanil and N.C. Baker, "Application and Development of Multiple Teaching Styles to an Engineering ITS", *7th World Conference on Artificial Intelligence in Education, Association for the Advancement of Computing in Education*, vol. , (1995), p. 315. Published

Book(s) or other one-time publication(s):

Internet Dissemination:

http://epitome.ce.gatech.edu/

```
This site contains information about all the work that has taken place
related to this award and other awards regarding engineering education
using and assessing technology.
```

Other specific products:

Software (or netware)

```
Problem Generator for Reinforced Concrete.  This software is web based
and allows students to choose either to create problems, have a
problem created, or see examples of problems related to one of nine
objectives in a civil engineering course on reinforced concrete.  The
software is in english and spanish.

This software is web based and as such is available for anyone to
utilize via the web (http://www.ce.gatech.edu/~ce4214), but soon to be
moving to (http://www.ce.gatech.edu/~cee4520).  See the EPITOME
project pages for the latest information
(http://epitome.ce.gatech.edu)
```

Software (or netware)

```
Trickshot! - A computer program that simulates particle dynamics on
the surface of a billards table.  The user is allowed to change the
way in which balls bounce off each other, off the cushions, and the
user can add gravitational attraction of the balls to each other.
```

Other features include a wind vector on the table top. The software system runs in MS-DOS and has a Toolbook explanation software package coupled to the simulation.

The software is available for download from the EPITOME web site (http://epitome.ce.gatech.edu)

Software (or netware)

Interactive Visualizer - a virtual reality environment that incorporates dynamic properties of the objects in the environment. The software is written for SGI workstations, but has a simple version ported to OpenGL for Windows NT.

Information is available at the EPITOME web site (http://epitome.ce.gatech.edu) under the Interactive Visualizer button.

Software (or netware)

IOWA - Instructional Objectives Writing Assistant - is a web-based assistant to help faculty and instructors write good course objectives.

The assistant can be run from the EPITOME web site (http://epitome.ce.gatech.edu)

Teaching aids

Sustainable Education Building Construction - a web site contains both still images and video footage of the construction of the 3 story, 30,000 square foot building located on Georgia Tech's campus. The contents of this web site have been utilized in many civil engineering classes, both at Georgia Tech and abroad.

The information is available at http://seb.ce.gatech.edu/

Contributions:

Contributions within Discipline:

The principal area where this research has contributed is in the education of civil engineering students. The work funded by this research has been used by faculty in the School of Civil & Environmental Engineering at Georgia Tech, faculty in other departments of Civil Engineering both in the US and abroad (via the web interfaces). The findings from this work have influenced the curriculum at Georgia Tech in structural mechanics at the undergraduate level, both in minor revisions and in the creation of the semester based program that Georgia Tech created in its transition away from a quarter-based program. Findings from this work are also found in a SUCCEED workshop, Effective Teaching with Technology.

Contributions to Other Disciplines:

The work, while directed at civil engineering education, has provided techniques and assessments which are applicable to all fields of engineering. Consultation with faculty in electrical, aerospace, and mechanical engineering have taken place regarding edcuational activities they desire. The assessments appear to relate to scientific fields where visualization is a predominant mode of learning.

Contributions to Education and Human Resources:

The results of this work have contributed to a SUCCEED workshop entitled, Effective Teaching with Technology. In this workshop and associated workbook, findings are presented to other engineering faculty about using technology in the classroom.

Contributions to Resources for Science and Technology:

The work funded by this research project has impacted Georgia Tech and civil engineering. Specifically, industry was attracted to this research and the concept of sustainability (matching funds sponsor) and contributed money to Georgia Tech to build a 3 story, 30,000 square foot building, the Sustainable Education Building. This building opened in October 1998 and contains electronic classrooms, a multimedia theater for distance learning, research facilities, and faculty/staff/student offices.

Secondly, the research has contributed to civil engineerings presence on the world wide web. The initial products of this research created the School of Civil Engineering's web site (www.ce.gatech.edu) and now includes on-line courses by several faculty, including some offered at a distance. The Civil Engineering Virtual Library, part of the original W3 consortium still exists and is an active repository for sites related to civil engineering activities, both professionally and academically.

Contributions Beyond Science and Engineering:

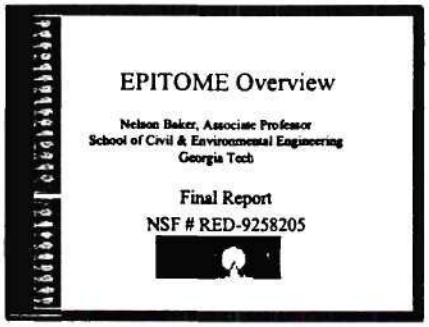
The work in virtual reality has lead Spectra Precision Software to create a product called TerraVista for the display of engineering site topography in three dimensions. This software package is commercialized and contains some findings from this research.

Categories for which nothing is reported:
Products: Book or other one-time publication

Submit Return

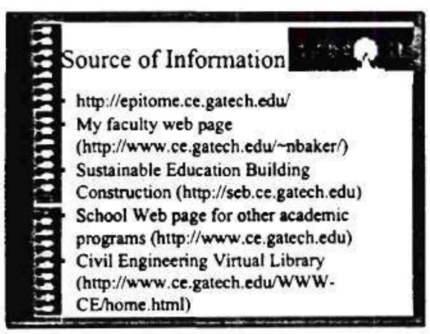
View Attached PDF File

Slide 1



Slide 2

Slide 3



Slide 4

Mission

EPITOME: Engineering Platform for Intelligent Tutoring and Multimedia Experiences

To investigate through research and assessment the impacts of computer enhancing educational material on engineers, both students and practicing professionals.

Slide 5

Funding

- National Science Foundation
- Keck Foundation
- GE Foundation

Slide 6

Tools

- Trickshot!
- CELL (Civil Engineering Learning Library)
- Problem Generator
- Student Model
- ITS-Concrete, ITS-CPM, ITS-Progress
- Interactive Visualizer
- Gradebook
- SEB (http://seb.ce.gatech.edu/)
- Olympic Venues Construction

Slide 7

Premise

- Software Tools based on Cognitive theory
  - Bloom's Taxonomy
  - Learning Styles
  - Teaching Styles
  - Anchoring, reflection, scaffolding, visualization
  - Active Learning
- Software must be assessed

Slide 8

Bloom's Taxonomy (Cognitive Domain)

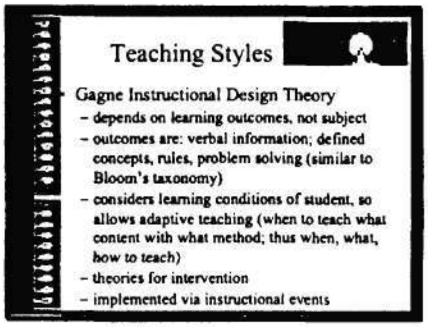
- 6 Levels of Educational Objectives
  - Level 1 - Knowledge/Information
  - Level 2 - Comprehension
  - Level 3 - Application
  - Level 4 - Analysis
  - Level 5 - Synthesis
  - Level 6 - Evaluation

Slide 9

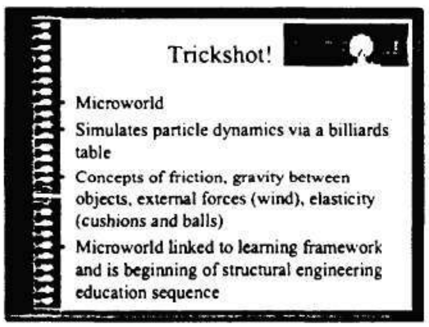
Learning Styles

- Dimensions include:
  - Input: Visual vs. Verbal
  - Perception: Intuitive vs. Sensing
  - Organization: Inductive vs. Deductive
  - Processing: Active vs. Reflective
  - Understanding: Sequential vs. Global
  - Mathematical Example vs. Theory

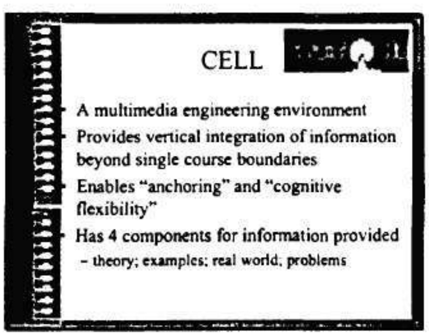
Slide 10



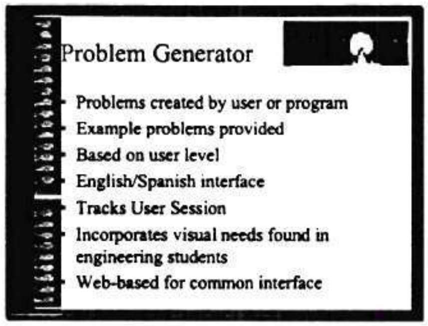
Slide 11



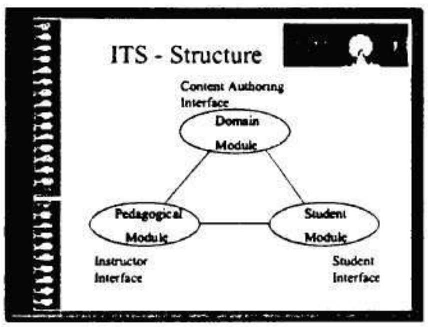
Slide 12



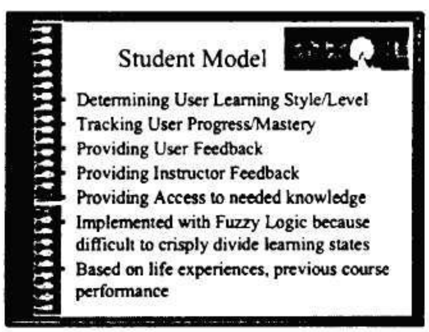
Slide 13



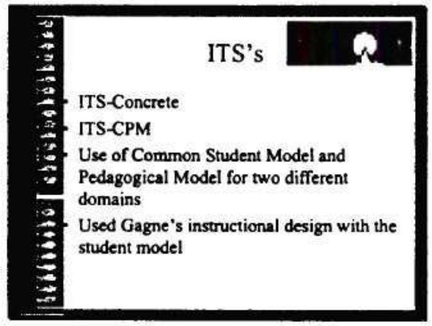
Slide 14



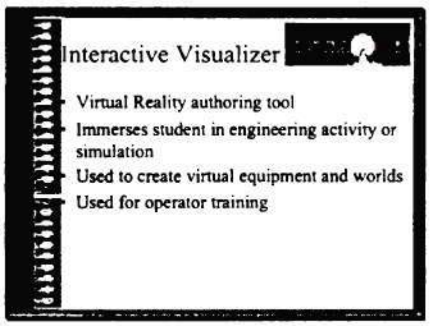
Slide 15



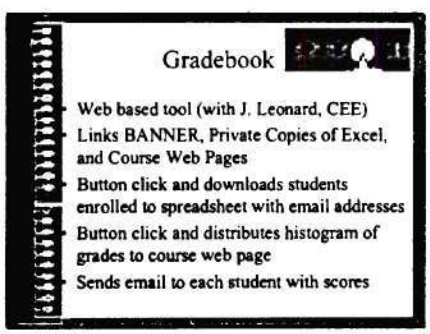
Slide 16



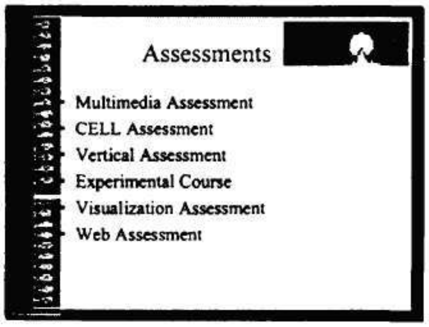
Slide 17



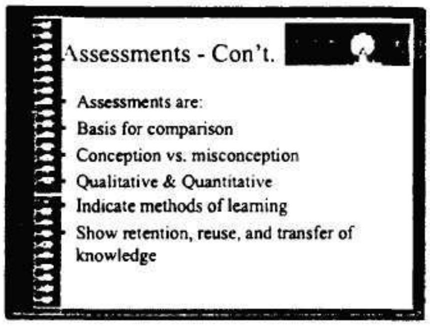
Slide 18



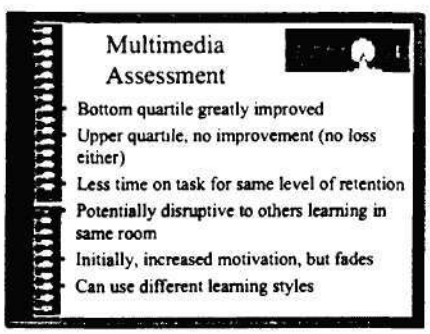
Slide 19



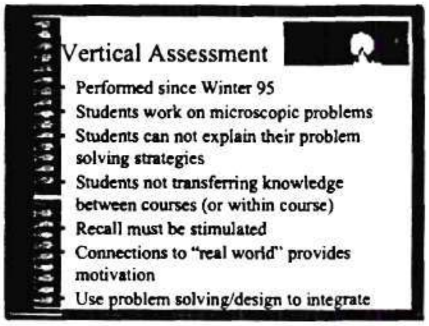
Slide 20



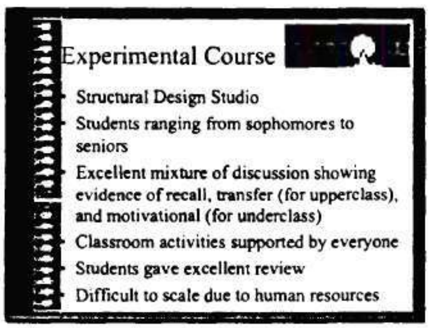
Slide 21



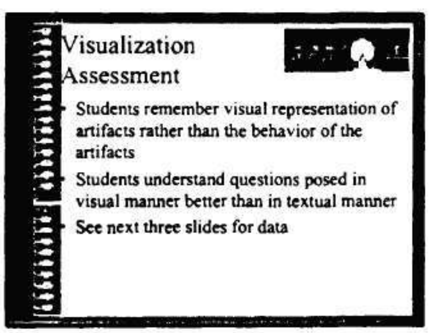
Slide 22



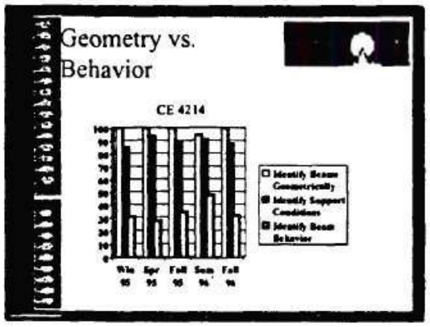
Slide 23



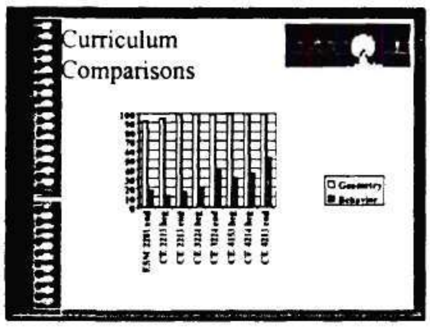
Slide 24



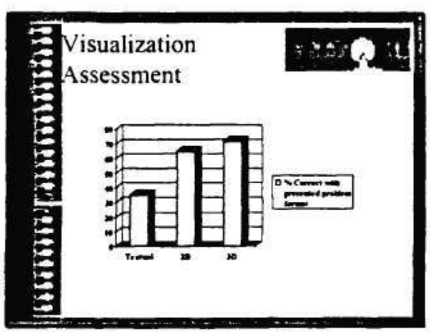
Slide 25



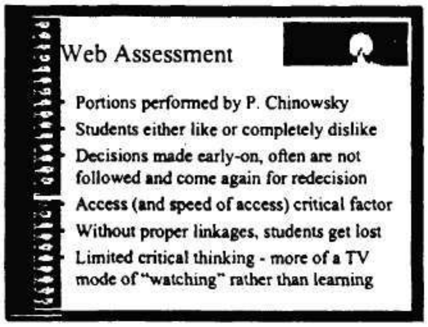
Slide 26



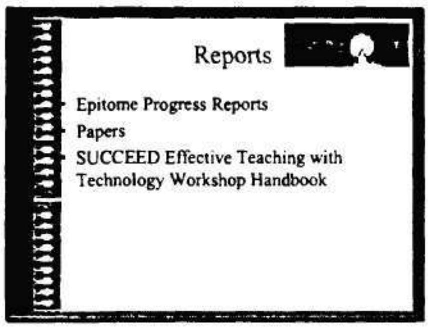
Slide 27



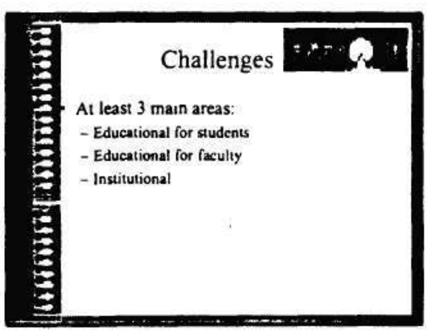
Slide 28



Slide 29



Slide 30



Slide 31

Educational - Student Challenges

- Student Expectations
  - Production quality
  - personal vs. computer instruction
  - learning computer interface rather than content
- Vertical migration of information
- Educational objectives rather than course

Slide 32

Education - Faculty Challenges

- Learning time for faculty to use/incorporate
- Development time for faculty
- Incentives to spend the time needed
- "Fears" of not-in-control of knowledge dissemination
- Limited assessments showing benefits
- Lack of peer reviews

Slide 33

Institutional Challenges

- Availability of equipped classrooms
- Ability to do long term assessments
- Contextual influences on assessments
- Maintenance of site/software/information (and funding to do so)
- Sustaining graduate students
- Incorporating into mainstream (scale-up, time, resources)